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MATHEMATICAL GNOSTICS FOR FORECASTING OF ENTERPRISE FINANCIAL EQUILIBRIUM

This article describes the mathematical gnostics application in modelling of enterprise financial equilibrium. Regression model for forecasting of enterprise financial equilibrium is obtained on the basis of the suggested methodology. The role of factors in building the forecast of enterprise financial equilibrium is explored.

Keywords: financial equilibrium; financial health; mathematical gnostics; forecasting.

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ПРОГНОЗУВАННЯ ФІНАНСОВОЇ РІВНОВАГИ ПІДПРИЄМСТВА НА ОСНОВІ МАТЕМАТИЧНОГО ГНОСТИЧНОГО АНАЛІЗУ

У статті розкрито застосування математичного гностичного аналізу для моделювання фінансової рівноваги підприємства. На його основі виведено регресійну модель для прогнозування фінансової рівноваги підприємства. Досліджено участь факторів у формуванні прогнозу фінансової рівноваги підприємства.

Ключові слова: фінансова рівновага; фінансове здоров'я; математичний гностичний аналіз; прогнозування.

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ПРОГНОЗИРОВАНИЕ ФИНАНСОВОГО РАВНОВЕСИЯ ПРЕДПРИЯТИЯ НА ОСНОВЕ МАТЕМАТИЧЕСКОГО ГНОСТИЧЕСКОГО АНАЛИЗА

В статье раскрыто применение математического гностического анализа для моделирования финансового равновесия предприятия. На его основе получена регрессионная модель для прогнозирования финансового равновесия предприятия. Исследовано участие факторов в формировании прогноза финансового равновесия предприятия.

Ключевые слова: финансовое равновесие; финансовое здоровье; математический гностический анализ; прогнозирование.

Problem statement. Financial equilibrium is an important factor in corporate financial management. Financial equilibrium is a special functioning feature of company's finance based on the balance of its liquidity, profitability and probability of financial instability.

Scientists often make some analogy between a sick person and a company in crisis. That's why the term "financial health" is used by foreign economists for the designation of crisis-free position of an enterprise (Altman and La Fleur, 1984; Dhaliwal et al., 2010; Kliestik et al., 2015; Kumari, 2013), while the category of "equilibrium" is associated with macroeconomics mostly (Bisin et al., 2014; Nagurney and Dong, 1996). But, the conceptual apparatus of Ukrainian economics has only the term "financial equilibrium" (Blank, 2004; Unkovskaya, 1997). Similarities between "financial equilibrium" and "financial health" are evident, because both mean "no bankruptcy" (Altman and La Fleur, 1984; Li, 2014; Shahedi et al., 2014).

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Any enterprise should monitor deviations from financial equilibrium in order to prevent crisis. Different forecasting methods of company's financial health are used in today's practice. Let us consider financial equilibrium forecasting methods.

Literature review. There is a number of forecasting methods for enterprise financial health. The most common is discriminant analysis. Among the first to apply this method were E.I. Altman and J.K. La Fleur who back in 1984 assessed the true value of bankruptcy probability. Further, discriminant analysis was also applied by N. Kumari (2013), W.G. Li (2014) and many others. This method allows any company determine whether its financial situation is balanced or unbalanced.

To other forecasting methods of financial health belong: regression analysis, studied by D.S. Dhaliwal, O.Z. Li and H. Xie (2010); logit analysis implemented by T. Kliestik, K. Kocisova and M. Misankova (2015); neural networks developed by S.H. Shahedi, A.M. Sharifabadi and M. Moeinadin (2014) etc. Application of these methods is directed to make models less sensitive to non-normal distributions. They are relevant, because financial data and ratios rarely have normal distribution.

Unresolved issues. However, the significance of this issue stimulates to continue research related to diagnostics of corporate financial equilibrium. Forecast of enterprise financial equilibrium should not be the goal per se, it should serve as a support tool in decision-making. Most management decisions are made under conditions of limited information. In this case it's necessary to use mathematical gnostics for the analysis of uncertain data. Mathematical gnostics is based on quantification theory, riemannian geometry, relativistic mechanics, thermodynamics and algebra. The concept of mathematical gnostics has been developing by foreign scientists since 1984 (Kovanic and Humber, 2009: 47). Despite its wide application in the world of science it is insufficiently developed in Ukraine.

The research objective. Mathematical gnostics offers new methods to process uncertain data. In this paper we are going to use gnostic instruments for forecasting of enterprise financial equilibrium. Our purpose is to create a robust regression model of financial equilibrium based on the gnostic theory of uncertain data. The object of this study is financial equilibrium at Public Joint Stock Company "Plant "Ltava" (PJSC "Plant "Ltava").

Key research findings. Let us consider the practical application of multidimensional regression modelling using mathematical gnostics. Algorithms of mathematical gnostics are implemented in the software environment "R-project" by using the programming language "R". Data processing, implementation of distribution function, a function definition uniformity, cluster analysis, factor analysis, regression modeling are allowed to be performed in "R-project". Data is exported from "RExcel" to "R-project". The calculation results are obtained in "RExcel" and in "R-project".

To construct a multivariate regression model for analysis of company financial equilibrium it is necessary to use the function GWLS (gnostic weighted least squares). This function "performs robust estimation of the parameters of linear multidimensional regression models of both explicit and implicit type based on the gnostic theory or – alternatively – on the methodology of both classical and robust statistical theory" (Kovanic, 2011: 327).

The financial ratios of PJSC "Plant "Ltava" taken for analysis its financial equilibrium are presented in Table 1. This enterprise is one of the leading manufacturers of electrical connectors and switching products in Ukraine.

Here is the description of some of the selected factors. The resulting factor is working capital to current financial need ratio. It had introduced by H. Meunier, F. de Barolet and P. Boulmer (1970). This ratio shows a part of working capital in financing of current financial needs. Company's finance are considered to be balanced, when its working capital to current financial need ratio is equal to 1 or more. This indicator shows an upward trend at PJSC "Plant "Ltava" (Table 1). Herewith current financial need of the enterprise was fully covered by its working capital during 2004–2015.

5 variable factors are taken for analysis of enterprise financial equilibrium. They represent different aspects of enterprise financial health: liquidity, solvency, profitability and financial stability.

The first factor is net cash flow to working capital ratio. It describes the role of working capital in the formation of enterprise liquidity. To be exact, it means how much net cash flow the enterprise receives from each currency working capital. It is worth noting that financial health's weak area at "Plant "Ltava" is unstable positive net cash flow (Table 1). This suggests that enterprise's cash flows are unbalanced.

The second factor is current ratio. It is a solvency ratio measuring enterprise ability to pay short-term obligations. It is calculated as the ratio of current assets to current liabilities. It should be equal to 2 or more. This indicator at "Plant "Ltava" was exceeding the optimum limit by 4–10 times during 2004–2015 years (Table 1). This means that enterprise's quite high solvency is instable.

The third factor is financial leverage. Financial leverage shows the level of involvement of borrowed capital in enterprise development funding. It is the ratio of total liabilities to shareholders' equity. The more debt financing is used by enterprise, the higher is its financial leverage. High degree of financial leverage means high load on current solvency and enterprise profitability. So, intensive growth of this ratio is able to have some negative impact on earnings per share, which is our fourth variable factor. The financial leverage of PJSC "Plant "Ltava" reflects its high financial stability (Table 1).

Earnings per share represent a part of enterprise's profit allocated to each outstanding share of common stock. It is calculated as the ratio of net profit to average outstanding common shares. Earnings per share are considered to be one of the most important variables for determining stock and business market value. Stable growth of shares profitability confirms high competitiveness of "Plant "Ltava" (Table 1).

Accounts payable turnover is the ratio measuring the speed of payment bills by enterprise. If the turnover ratio declines, it will indicate more slow paying off creditors debts. This may be the indicator of worsening financial health. The accounts payable turnover at "Plant "Ltava" has been slowing down since 2004 (Table 1). This reflects on the increase of enterprise's current financial need.

Processing data in "R-project" was made by the following commands:

$$R1 < -PredMD(t(RATIOS), Dep = 6, ww = 6); \quad (1)$$

$$R2 < -PredMD(t(RATIOS), Dep = 6, ww = 7); \quad (2)$$

$$R3 < -PredMD(t(RATIOS), Dep = 6, ww = 8); \quad (3)$$

$$R4 < -PredMD(t(RATIOS), Dep = 6, ww = 9); \quad (4)$$

Table 1. Data matrix of PJSC "Ltava" for financial equilibrium forecasting based on mathematical gnostics, 2004–2015, calculated by the author on the basis of (Finansova zvitnist, 2004–2015)

Factor	Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Net cash flow to working capital ratio		0.0010	-0.0004	0.00002	0.0002	0.0112	-0.0085	0.0002	0.0325	-0.0064	-0.0122	0.0896	-0.0270
Current ratio		23.504	21.450	16.995	9.397	10.316	10.233	9.819	10.103	10.809	24.143	8.839	17.080
Financial leverage		0.0390	0.0428	0.0614	0.1084	0.0867	0.0932	0.1033	0.0924	0.0921	0.0461	0.1068	0.0516
Earnings per share		0.748	0.644	0.636	0.839	1.071	1.940	3.515	2.617	5.092	5.758	8.965	14.502
Accounts payable turnover ratio		16.279	16.379	15.787	9.028	10.305	9.220	9.432	8.466	8.886	15.541	6.776	10.671
Working capital to current financial need ratio		1.139	1.230	1.207	1.323	1.377	1.419	1.629	1.653	2.125	2.560	2.815	4.183

Table 2. Impact of variable factors on financial equilibrium of "Plant "Ltava" and its forecast, calculated by the author in "R-project" on the basis of Table 1

Argument	Net cash flow to working capital ratio	Current ratio	Financial leverage	Earnings per share	Accounts payable turnover ratio	Predictive value of working capital to current financial need ratio	PrErr (Working capital to current financial need ratio)
Year							
2010	0.000885	-1.81065	1.038997	1.539405	1.383196	2.151829	0.522966
2011	-0.4514	-4.31913	2.978949	0.650927	2.055827	0.915174	-0.737848
2012	-0.06721	-2.37858	1.425711	1.362749	1.483565	1.826235	-0.298273
2013	-0.07838	-5.47986	2.944599	1.873763	2.603047	1.86317	-0.696578
2014	0.606396	0.064046	-1.20232	2.373909	1.630936	3.472964	0.658179
2015	-0.02323	0.180047	-2.88793	3.650466	2.814808	3.734163	-0.449291

$$R5 < -PredMD(t(RATIOS), Dep = 6, ww = 10). \quad (5)$$

Explanation of these commands elements is as follows: *RATIOS* – data matrix name; *Dep* = 6 – resulting factor is located on the sixth row of the data matrix; *ww* – length of "training" interval – number of years that "R-project" takes to build forecast based on time series data.

Let us consider the results obtained in "R-project" (Table 2).

Form the results of mathematical gnostics' application for "Plant "Ltava" financial equilibrium forecasting we can make the following conclusions. The structure of factors' influence on enterprise's financial equilibrium was undergoing some significant changes during 2010–2015 (Figure 1).

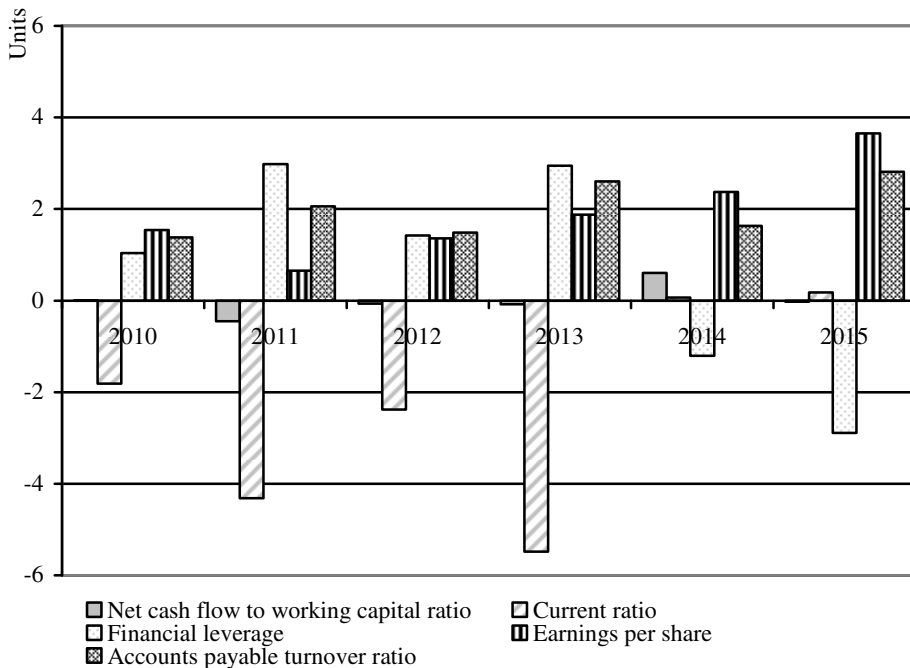


Figure 1. Structure of factors influence on financial equilibrium of "Plant "Ltava", 2010–2015, compiled by the author on the basis of Table 2

Current ratio was having its dominant influence on the financial equilibrium of PJSC "Plant "Ltava" since 2010 till 2013. And this influence was negative. Obviously, financial health of "Plant "Ltava" was affected by the consequences of defaults wave in Ukrainian real sector provoked by the financial crisis of 2008–2009. At that time enterprise's strong qualities were steadily increased profitability and balanced capital structure, due to which the financial equilibrium of "Plant "Ltava" was maintained.

Among the positive factors, the most significant was earnings per share. Its influence was dominating till 2015. This means the formation of robust preconditions for business value growth.

PJSC "Plant "Ltava" financial equilibrium is not compromised despite the negative impact of financial leverage in 2014. Magnification of its accounts payable turnover ratio compensated the negative impact of increased part of liabilities in total

capital. Noteworthy, during 2010–2015 the accounts payable turnover ratio was keeping the third rank in the factors impact structure on enterprise financial equilibrium.

Therefore, overcoming some negative impacts coming from external and internal factors "Plant "Ltava" was supporting its own financial equilibrium during 2010–2015. It is important to note that the forecast of enterprise financial equilibrium in 2016–2017 shows positive dynamics (Figure 2).

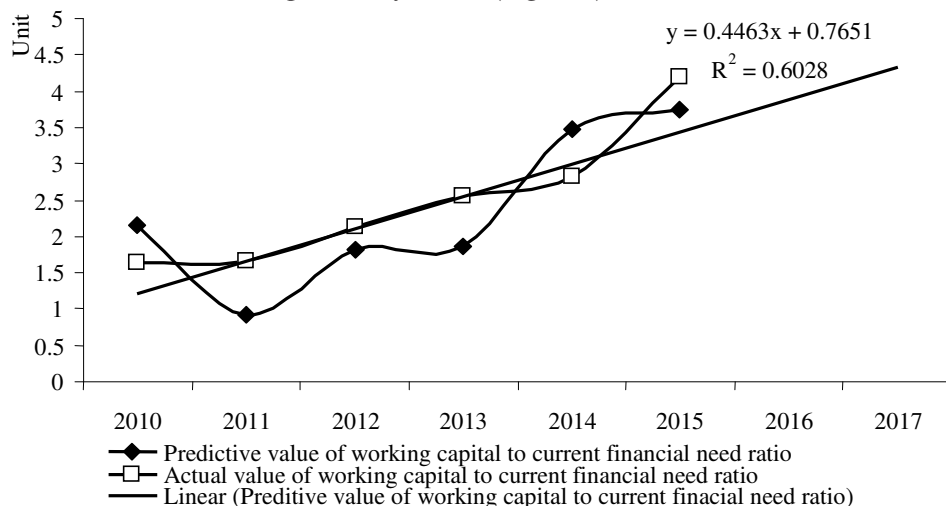


Figure 2. Financial equilibrium forecast for "Plant "Ltava", 2016–2017, compiled by the author on the basis of Tables 1 and 2

Financial equilibrium's forecast with the lowest variability, which corresponds to the standard deviation at the level of 0.184695, can be described by the following regression model:

$$Y = 0.859164X_1 + 0.010541X_2 - 0.14896X_3 + 0.251715X_4 + 0.263785X_5, \quad (6)$$

where X_1 – net cash flow to working capital ratio; X_2 – current ratio; X_3 – financial leverage; X_4 – earnings per share; X_5 – accounts payable turnover ratio; Y – working capital to current financial need ratio.

Coefficient's values of regression model (6) are taken from Table 3 (column "Coeffs"). Let us interpret their meanings.

Financial equilibrium will be strengthened, if net cash flow to working capital ratio increases by one. It will be expressed as the resulting factor's growth (Y) to 0.859164.

Increase of current ratio will conduce to strengthening financial equilibrium. If the current ratio grows to one, the working capital to current financial need ratio will increase by 0.010541.

In case when financial leverage increases by one, the working capital to current financial need ratio will decrease by 0.14896.

It is explained by the presence of capital-raising's efficiency border. This has already been reached by "Plant "Ltava". For this reason, any attraction of new loan capital may worsen enterprise's financial health.

Table 3. Components of the function GWLS, characterizing the model of "Plant "Ltava" financial equilibrium forecast, calculated by the author in "R-project" on the basis of Table 1

Component Factor	Coeffs	Std (C[k])	Mean (x[,k])	STD (x[,k])	Mean (Cx[,k])	STD (Cx[,k])	Probability value
Net cash flow to working capital ratio	0.859164	1.559317	0.010624	0.030464	0.009128	0.026174	0.595053
Current ratio	0.010541	0.030877	13.21034	5.573166	0.139253	0.058748	0.74064
Financial leverage	-0.14896	0.036346	13.35293	5.239638	-1.98912	0.780521	0.002683
Earnings per share	0.251715	0.01608	3.107811	2.759121	0.782282	0.694512	0.0000001
Accounts payable turnover ratio	0.263785	0.02123	10.98197	3.514985	2.896883	0.927201	0.0000006

Increase of earnings per share would enhance enterprise financial equilibrium. If the profitability rate increases by one, working capital gain will make 25% of enterprise's current financial needs.

Acceleration of accounts payable turnover entails financial equilibrium strengthening. It will be expressed as 0.263785 gain of the working capital to current financial need ratio.

Let us consider other components of the GWLS function (Table 3).

STD(C[k]) is standard deviation of the coefficients. It shows that the variation of factor X1 is more than the variation of other factors. This is caused by high volatility of net cash flow under economic instability. As a consequence, factor's importance X1 (Mean (x[,y]) is the lowest. At the same time standard deviation of the net cash flow to working capital ratio is the lowest too. It allows us speak about robust factor X1. Standard deviations of other factors are within the limits of confidence. Hence, their variations are insignificant, and their significance levels are sufficient.

Component "Mean(Cx[,k])" is mean impact of variable factors on the resulting factor. Two factors have the biggest impact on financial equilibrium. These are financial leverage and accounts payable turnover ratio. It is important for financial management of "Plant "Ltava".

Hypothesis expressed by the regression model (6) is fair, because probability's evaluation of null hypothesis indicates its insignificance (column "Probability value" of Table 3).

Conclusions. Forecasting results for enterprise financial equilibrium has been obtained on the basis of mathematical gnostics. Advantages of its application are: individual simulation of financial equilibrium, taking into account enterprise's specific features; forecasting is performed not only for the result indicator (Y), but also for factors influence structure on it; identification of factors priority change in financial equilibrium formation.

Practical importance of this study results is in their application in financial equilibrium management. Forecast of the working capital to current financial need ratio at "Plant "Ltava" has shown an increasing trend of its financial equilibrium. Its preservation requires the enterprise take into account the degree of each factor's role in financial equilibrium formation.

A peculiarity of mathematical gnostics application for financial equilibrium forecasting is the need for its periodical repeated modelling, taking into account some new conditions of enterprise's financial health. The regression model (6) is fair for PJSC "Plant "Ltava" at the current stage of development. The robust prediction interval of its financial equilibrium is 2 years. After this period of time, it is recommended to reconsider, the factors' influence on enterprise's financial equilibrium.

Prospects for further research include mathematical gnostics application for modelling of Ukrainian enterprises financial equilibrium. This will contribute to enterprises unhealthy financial status prevention.

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